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ORIGINAL

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Patents Act 1990

Provisional Specification for the Invention Entitled

APPARATUS FOR REDUCING THE DIAMETER OF ROUND PIPE AND TUBING

The invention is described in the following statement:

APPARATUS FOR REDUCING THE DIAMETER OF ROUND PIPE AND TUBING

This invention relates to methods and apparatus for correcting by reduction the diameter of round pipe or tubing. More particularly, it relates to such methods and apparatus employing a plurality of rollers for the purpose.

For a variety of reasons, in the fabrication of pipe and tubing by rolling up a tubular form from a flat strip or skelp and seam welding the abutting edges, it is impossible to maintain precise control of diameter. Particularly in larger diameters and where lighter gauge material is used, for example in diameters above 150 millimetres or where the wall thickness is less than 2% of diameter, pipe and tubing fabricated in this way may not be perfectly round.

Many applications exist in which the diameter of pipe and tubing must meet precise specifications and a variety of methods has therefore been developed to correct diameter. Where diameter of pipe or tubing has to be increased, it is common to pass a cylindrical die of some suitable hard material and having an external diameter somewhat greater than the internal diameter of the pipe or tube through the lumen of the pipe or tube to stretch it. Where more than a minor correction is required, consecutive passes of dies of increasing diameter may be required, the internal surfaces of the pipe or tube lumen may require lubrication, scoring of the internal surfaces is common and some degree of wall thinning will occur. The

process has the advantage of being operable on a continuous basis. In another method, the internal diameter of pipe or tubing is increased by subjecting the interior of short lengths to hydraulic pressure to expand it into an enclosing female die. Use of this method is normally confined to short lengths of pipe or tubing and has the disadvantages of slowness and the fact that it cannot be operated on a continuous basis. Both methods are well known in the art.

Where diameter of pipe or tubing has to be decreased, it is common to roll it down by passing the pipe or tubing through a plurality of concave rollers arranged such that their diameters extended meet at a common point and with their collective concavities more or less forming a complete circle slightly smaller than the final diameter of pipe or tubing required. The rollers are normally driven in rotation and pipe or tubing to be resized is fed between them and is thereby cold worked to a smaller diameter. Unless the pipe or tubing is stretched at the time, some degree of wall thickening will occur. An example of this method is that taught by United States Patent No. 5,533,370. It is notable that this method includes provision for final sizing to be performed by drawing the rolled pipe or tube through a female sizing die. Disadvantages of this method are the fact that only relatively small decreases in diameter may be achieved in a single pass, normally of the order of 0.2 to 0.4mm, that what is effectively a wiping action of the rollers may scuff or mar the external surfaces of pipe or tubing (an important point in stainless steel products), and the fact that the method is relatively ineffective in large, relatively thin-walled pipe or

tubing. The scuffing or marring of external surfaces is particularly pronounced in larger diameter pipe or tubing where the method is performed using only two rollers having deep concavities. Obviously, as suggested in the example cited, the diameter of pipe or tubing may be reduced by drawing it through a female sizing die. Where this method is employed, the pipe or tube may require lubrication, the external surface of the pipe or tubing is frequently scored by asperities in the die and some wall thickening and elongation may occur. An example of this method is that taught by United States Patent No. 4,057,992 in which both internal and external dies are used in what is normally a second or third manufacturing operation.

Another example of diametral reduction by rolling, in this case described at spin forming, is that taught by United States Patent No. 6,233,991 in which a short length of pipe or tubing is rotationally supported only by clamps at each end and a plurality of cylindrical rollers is brought to bear against the outer surface of the length of pipe or tubing while it is rotated, thereby reducing its diameter and, if required, rendering it in tapered form. The method is applicable only to short lengths of pipe or tubing and obviously cannot be operated as a continuous process. Of relevance to the present invention is United States Patent No. 4,242,894 in which thin-walled metallic tubing is formed from a solid blank in an Assel rolling mill. In this case, provision is made to vary the wall thickness of the formed tubing by adjusting the radial positions of a plurality of forming rollers. Adjustment is effected by increasing the skew of short shafts upon

which the forming rollers are rotationally supported, thereby radially displacing the rollers inwardly or outwardly. The ends of the short shafts are rotationally supported in suitable bearings accommodated within the ball parts of ball joints, which ball parts move in complementary sockets to permit skewing of the shafts.

Applications are also common in which laminated pipe or tubing is made by drawing one piece of pipe or tubing into the lumen of another. Where, for example, the inner pipe or tube is made from a polymer material, it is common to temporarily reduce its diameter by passing it between concave rollers or through a female sizing die in the manner described and, when it is in place, expanding it by the application of internal fluid pressure to make a tight fit inside the outer pipe or tube. Additionally, to ensure a more secure capture of the inner pipe or tube, the outer pipe or tube may subsequently be reduced in diameter using one of the methods described. Where both the inner and outer pipes or tubes are of metal, the inner is captured simply by reducing the diameter of the outer.

The object of the present invention is to provide a method and apparatus for reducing the diameter of pipe or tubing; which may readily be precisely adjusted to alter the diameter reduced; which may be operated on continuous or short lengths of pipe or tubing; which may be made self-correcting; which may also form part of a tube straightening process; which acts without marring the external surface of the pipe or tubing; which is capable of effecting a greater degree of reduction in diameter in a single pass than other systems; which leaves the pipe or tubing properly round;

which may be ganged into a multi-stage operation; which acts without the necessity to lubricate the pipe or tubing; and which is effective in treating both thin and thick-walled pipe or tubing.

According to the present invention, the diameter of pipe or tubing is reduced by passing it through a rotating apparatus comprising a supporting cylinder in which is provided a plurality of closely spaced, skewed cylindrical rollers of a rigid, hard material which are brought to bear on the external surface of the pipe or tubing as it passes through said apparatus. Said rollers are supported in a cylindrical array on a common pitch circle and are rotationally supported in suitable bearings provided in the end flanges of said supporting cylinder, said end flanges being also provided with apertures to permit the ingress and egress of the pipe or tubing to be treated. One or both or said end flanges are capable of rotational displacement within the ends of said supporting cylinder, thereby adjusting the degree of skew of said rollers which, although they are displaced relative to the longitudinal axis of said supporting cylinder, remain in a plane parallel to said longitudinal axis. Said bearings of said rollers are themselves supported in part-spherical housings which are, in turn, accommodated within complementary cups formed in said end flanges such that said rollers may continue to be rotationally supported in said end flanges even while skewed. Said supporting cylinder is itself rotationally supported in one or more bearings which permit it to rotate about its longitudinal axis, driven by a suitable driving motor. In operation, the degree of skew of said rollers is adjusted such that the pipe or tubing to be

treated may just enter between them and, with the pipe or tubing entered, are skewed to a greater degree to bring narrow, centrally-located contact zones on them to bear against the outer surface of the pipe or tubing with a desired force. As said pipe or tubing passes at a steady speed through said cylindrical array of rollers, said supporting cylinder is rotated by its driving motor, causing said contact zones of said rollers to describe contiguous helical paths along the external surface of said pipe or tubing, locally applying a compressive force to said pipe or tubing in excess of the yield stress of its material and thereby causing said pipe or tubing to adopt a set at a smaller diameter. The passage of said contact zones of said rollers over the outer surface of said pipe or tubing causes the surface to be attractively burnished without marring, any out-of-roundness of said pipe or tubing is simultaneously corrected and, should said pipe or tubing require straightening, moderate force simultaneously applied in an appropriate direction will effect this.

The various aspects of the present invention will be more readily understood by reference to the following description of preferred embodiments given in relation to the accompanying drawings in which:

Figures 1a, 1b and 1c are partial cross-sectional views of said supporting cylinder showing various positions of one of said cylindrical array of said rollers;

Figure 2 is a partial cross-sectional view of said supporting cylinder and said pipe or tubing to be treated showing the arrangement of some of said cylindrical array of said rollers in

relation to said pipe or tubing to be treated;

Figure 3 is a longitudinal cross-sectional view of said supporting cylinder, its supporting bearing and said pipe or tubing to be treated, said rollers having been deleted for simplicity of presentation;

Figure 4 is an end view of the components depicted in Figure 3;

Figure 5 is a longitudinal cross-sectional view of supporting means at one end of one of said rollers;

Figure 6 is a side view of the complete apparatus with said pipe or tubing to be treated passing through it;

Figure 7 is a longitudinal cross-sectional view of an alternative means of supporting said rollers;

Figure 8 is an end view of said supporting cylinder showing calibration detail;

Figure 9 is a partial side view of the central part of one said roller showing alternative shaping detail;

Figure 10 is a partial side view of the central part of one said roller showing another alternative shaping detail.

With reference to Figure 1a, roller 3 is rotationally supported within supporting cylinder 1 with its axis positioned on pitch circle 2 and parallel to the axis of said supporting cylinder. With reference to Figure 1b, the same roller is shown with its ends skewed 15° either side of the previous position. It can be seen that the distance 4 from the centre 5 of said

supporting cylinder to contact zone 6 of said roller has been reduced. With reference to Figure 1c, said roller is shown with its ends skewed a further 15° and distance 4 can be seen to have been further shortened. It may be appreciated from the figures that skewing of said rollers may be employed to bring their contact zones into forceful contact with and thereby to apply considerable force to the outer surface of said pipe or tubing to be treated when it is passed through said complete cylindrical array of said rollers.

With reference to Figure 2, a part of said cylindrical array of said rollers 3 is depicted, said rollers being positioned within supporting cylinder 1 with their axes at each end positioned on pitch circle 2. Skewing of said rollers has brought contact zones 6 into contact with the external surface of pipe or tubing to be treated 7. In the preferred embodiment, said rollers are made with a minimum practical diameter commensurate with a particular application in order to provide the maximum number of rollers in each said cylindrical array. This normally results in said rollers having a diameter approximately 20% of that of the pipe or tubing to be treated - for example, 18 rollers with a diameter of 28 millimetres are used in an arrangement to treat pipe or tubing with a diameter of 150 millimetres.

With reference to Figure 3, pipe or tube to be treated 7 is depicted passing through apertures 8 in end flanges 9, 19 of supporting cylinder 1 in the direction shown by arrow 23. A typical position of one of said cylindrical array of rollers is depicted by broken line 18, supporting provisions for this roller in end flanges 9, 19 having been cut away in the figure. End flange19 is fixed in one end of said supporting cylinder and

end flange 9 is captured in the other end of said supporting cylinder between shoulders 20, 21 while remaining free to be displaced in a rotational sense to effect skewing of said rollers. Supporting provisions (not shown) for the ends of said rollers are accommodated in apertures 10 provided in said supporting cylinder end flanges. Bearing 15 is positioned centred directly above the contact zones of said rollers. Mounting flange 12 is provided on the mid exterior surface of said supporting cylinder and attached to this with suitable fastening means is radial web 13, the periphery of which is formed into a first part of a housing for bearing 15. Cylindrical pulley 14 is formed on one side of said radial flange positioned towards its periphery. Radial mounting flange 22 is provided with holes 17 for mounting attachments (not shown) and its inner periphery is formed into a cylindrical extension 16 which incorpor-ates a second part of a housing for bearing 15. Mounting flange 22 is fixed with suitable fastenings to a supporting structure (not shown) and support-ing cylinder 1 is driven in a rotational sense by drive forces applied to pulley 14 through a suitable belt (not shown). In alternative embodiments, said pulley is replaced with a sprocket or gear (not shown) and said supporting cylinder is driven in a rotational sense by drive forces applied through one or more suitable chains or gears. As pipe or tubing to be treated 7 passes through the interior of said supporting cylinder and through said cylindrical array of rollers (not shown), the contact zones of said rollers pass over the external surface of said pipe or tubing following a helical path of which a typical one is indicated by arrow 24.

With reference to Figure 4, end flange 9 is restrained in a rotational sense by adjustable-length struts 33, the inner ends of which are pivotally attached to short shafts 34 formed on end flange 9 and the outer ends of which are pivotally attached to short shafts 35 formed on the ends of posts 32 fixed to the end exterior surfaces of said supporting cylinder. Skewing of said rollers is effected by lengthening or shortening said struts, thereby displacing end flange 9 in a rotational sense relative to said supporting cylinder.

With reference to Figure 5, the ends of rollers 3 are provided with tapered section 27, the end of which is formed into shaft 28. Shaft 28 is rotationally accommodated in needle bearing 29 which is, in turn, accommodated within part-spherical housing 26. Part-spherical housing 26 is accommodated within split cup 25 which is, in turn, accommodated within aperture 10 provided in end flange 9. Bearing 29 is captured on shaft 28 between shoulder 36 and retaining cap 30, said retaining cap being fixed to the end of said shaft by suitable fastening 31. Suitable means (not shown) are provided for the lubrication of said roller support means. Said split cup is provided with external flange 37 by means of which said split cup is retained in place in aperture 10 by suitable attachment means. The openings on either side of said split cup are suitably relieved to provide the requisite freedom of movement of roller 3. Shaft 28 and needle bearing 29 are made sufficiently long to accommodate the axial displacement of roller 3 caused by an increase or decrease in its degree of skewing. In an alternative embodiment (not shown), shaft 28 and needle bearing 29 are

positively captured in part-spherical housing 26 and the axial displacement of roller 3 caused by an increase or decrease in its degree of skewing is accommodated by axial displacement of end flange 9 within the end of supporting cylinder 1, said end flange being restrained against rotational displacement relative to said supporting cylinder by suitable splines, lugs or the like on one engaging complementary provisions on the other.

With reference to Figure 6, the assembly depicted in Figures 3 and 4 are mounted in moving frame 38. Said moving frame is slidingly supported by brackets 43, 44 bearing upon linear bearings 41, 42 travelling on rails 39, 40 fixed to upper surfaces of fixed frame 45. Pipe or tubing to be treated 7 is depicted passing through supporting cylinder 1 and its extension is supported on suitable supports (not shown). Pivot shaft 46 is fixed to a lower structural member of said moving frame towards one of its sides and valve 48 is fixed to a lower structural member of said fixed frame towards the second side of said moving frame. Link 49 connects the operating lever of said valve to said pivot shaft such that, as said moving frame is displaced along rails 39, said valve is progressively opened, said valve being fully closed at the left-hand limit of travel (as depicted) of said moving frame. A supply of compressed air at a suitable pressure is connected to said valve through air line 47 and air is supplied from said valve through flexible air line 50 to air motor 51. Said air motor drives pulley 52 through reduction gearbox 54, said pulley being connected to pulley 14 by belt 53 to drive supporting cylinder 1 in a rotational sense. Suitable gusseting is provided, as required, to stiffen said moving and fixed

frames. In operation, as said pipe or tubing passes into the apparatus from a tube mill, frictional forces applied through the contact zones of said rollers act to displace said moving frame along rails 39, 40, thereby partially opening valve 48 and actuating air motor 51 to drive supporting cylinder 1 in a rotational sense. Progressive displacement of said moving frame occurs until said air motor has reached a speed of operation matched to the speed of travel of said pipe or tubing. Further displacement of said moving frame then ceases. If the speed of travel of said pipe or tubing is reduced for some reason, the forces generated by said rollers upon said pipe or tubing act to displace said moving frame back towards its rest position, thereby closing valve 48 somewhat and reducing the speed of operation of air motor 51 and thereby the speed of rotation of supporting cylinder 1.

With reference to Figure 7, in an alternative embodiment, rollers 3 are rotationally supported in needle bearings 56 accommodated in bores 73 provided in shoulders 58 formed on the ends of mounting yokes 59. Each said mounting yoke is supported on shaft 64 pivotally supported in bearing 63 provided in the wall of supporting cylinder 1 and is retained in place by belville washers 65, washer 66 and circlip 67 or other suitable fastening. The rollers in said cylindrical array are simultaneously skewed by force applied through skewing rings 60 which are pivotally connected to pivots 61 provided on the ends of said yoke and retained in place by circlips 62. Thrust washers 57 are provided between the ends of rollers 3 and the inner surfaces of shoulders 58. Said supporting cylinder is increased in diameter as required to accommodate the arrangement described.

With reference to Figure 8, index mark 68 is provided on the face of end flange 9 and calibration marks 69 are provided on the end of supporting cylinder, said marks facilitating the adjustment of skew of said rollers.

With reference to Figure 9, in an alternative embodiment, shaft 3 is provided with a centrally-located, narrow, convex part 70 to permit a more localised force to be provided by said roller to said pipe or tubing to be treated.

With reference to Figure 10, in an alternative embodiment, shaft 3 is provided with a centrally-located, concave part 72 to permit a more dispersed force to be provided by said roller to said pipe or tubing to be treated.

With further reference to Figure 6, said fixed frame is fixed to floor 74 with suitable fastenings. Where required, said fixing provisions incorporate jacking means (not shown) to precisely align the apparatus with the axis of pipe or tubing 7 emerging from a tube mill (not shown). Said jacking means may be operated to effect the straightening of said pipe or tubing. In an alternative embodiment, sensors (not shown) are employed to detect the straightness or not of said pipe or tubing and, as required, one or more stepper motors (not shown) are employed to operate said jacking means to correct any deviation from straightness. A programmable logic controller or other microprocessor-based device is employed to process data from said sensors and control the operation, as required, of said stepper motors. In another alternative embodiment (not shown), said fixed

frame is permanently fixed to floor 74 and mounting flange 22 is supported on linear bearings slideably travelling on rails fixed to the vertical members of said moving frame, said linear bearings being displaced by ball screws driven by one or more stepper motors. Said stepper motors are employed to drive said ball screws to correct any deviation of said pipe or tubing from straightness. A programmable logic controller or other microprocessor-based device is employed to process data from said sensors and control the operation, as required, of said stepper motors.

With reference to Figures 3 and 6, in an alternative embodiment (not shown), air motor 51 is mounted directly to cylindrical extension 16 and drives supporting cylinder 1 in a rotational sense through one or more belts, chains or gears engaging pulleys, sprockets or gears formed on pulley 14 or on the external surface of supporting cylinder 1. In this embodiment, said moving frame is redundant and said apparatus is simply fixed to vertical members of said fixed frame. In other alternative embodiments, said air motor is replaced by a hydraulic motor, a stepper motor or other form of speed-controllable electric motor.

With further reference to Figure 6, in an alternative embodiment (not shown), the speed of travel of said pipe or tubing is detected by one or more encoders attached to forming wheels on said tube mill or on a jockey wheel which travels on said pipe or tubing. A programmable logic controller or other microprocessor-based device is employed to process data from said encoders and control the operation, as required, of one or more stepper motors which drive said supporting cylinder in a rotational

sense.

In an alternative embodiment (not shown), said apparatus is made in multi-stage form such that one of each or all units are employed to reduce the diameter of said pipe or tubing, correct its out-of-roundness or straighten it. It will be appreciated from further inspection of Figures 1a, 1b, 1c and 2 that the axes of said cylindrical arrays of rollers of consecutive units, regardless of their adjustments, will always be collinear. At the same time, the speed of travel of said pipe or tubing through consecutive units, regardless of their adjustments, will also remain approximately constant. This is a result of the fact that, as the degree of skew of rollers is increased, which would tend to increase the axial component of the vector triangle representing speed of travel of said pipe or tubing, the rotational component is automatically decreased in compensation. As a result, the said apparatus is thus very well suited for operation in multi-stage form. It should be noted also that the axial forces imparted to said pipe or tubing by operation of the said apparatus are high and no other means of propulsion or urging in an axial sense are required during its operation.

With further reference to Figure 4, in an alternative embodiment (not shown), one or more stepper motors mounted on the external surface of supporting cylinder 1 are employed to adjust the lengths of suitable ball screws (not shown) used in place of adjustable-length struts 33. Sensors are provided to detect the precise corrected diameter of said pipe or tubing and a programmable logic controller or other microprocessor-based device is employed to process data from said sensors and control the operation, as

required, of said stepper motors. Power is supplied to said stepper motors and their control is exercised through slip-ring provisions or wireless connections.

With further reference to Figure 3, it will be readily appreciated that supporting cylinder 1 may be made to be readily detachable from radial web 13 through the use of quick-release attachments (not shown) and a replacement said supporting cylinder installed in its place to accommodate said pipe or tubing of a different diameter.

Fig 1a

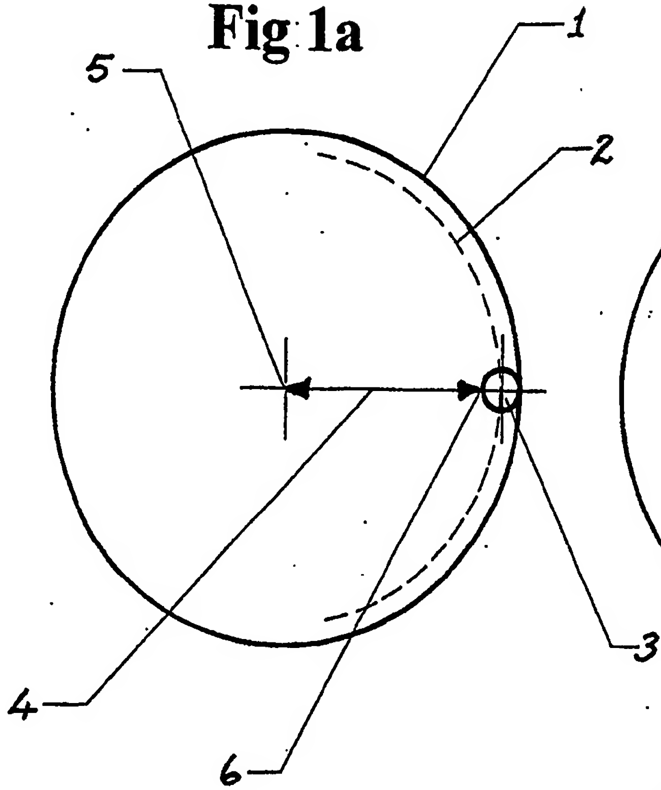


Fig 1b

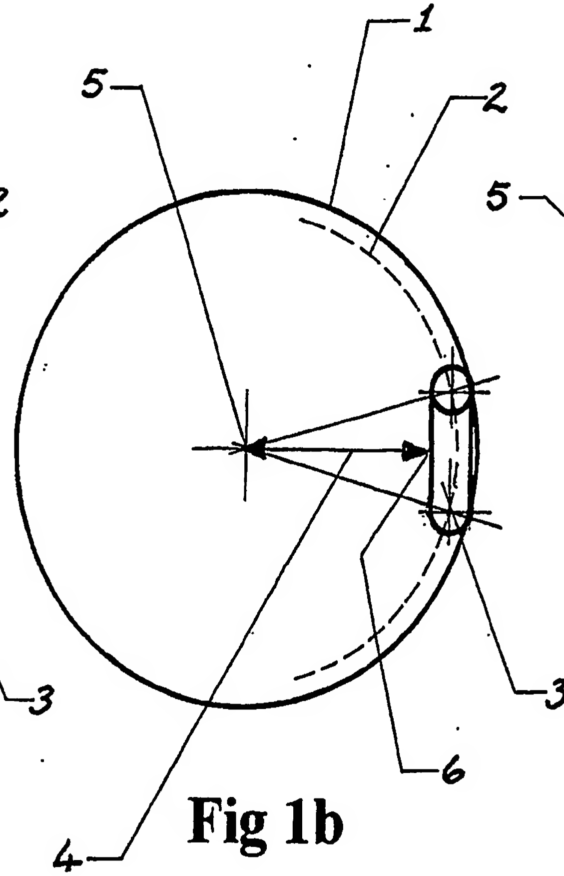
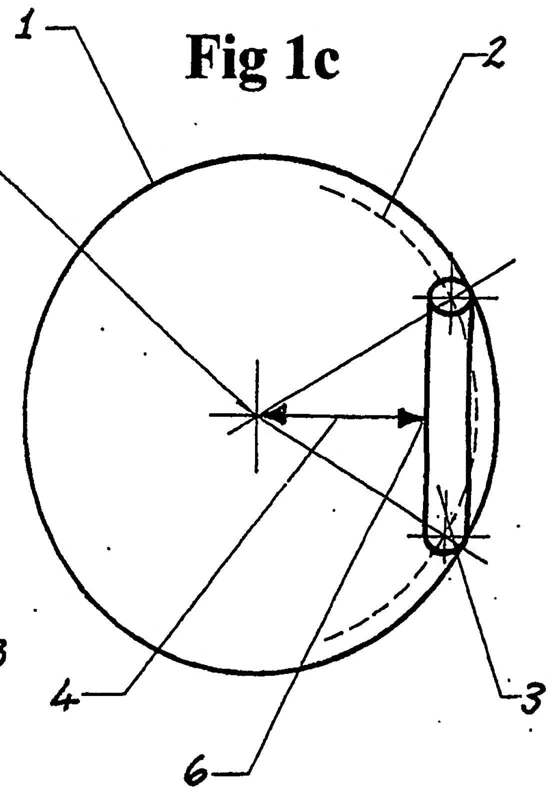


Fig 1c



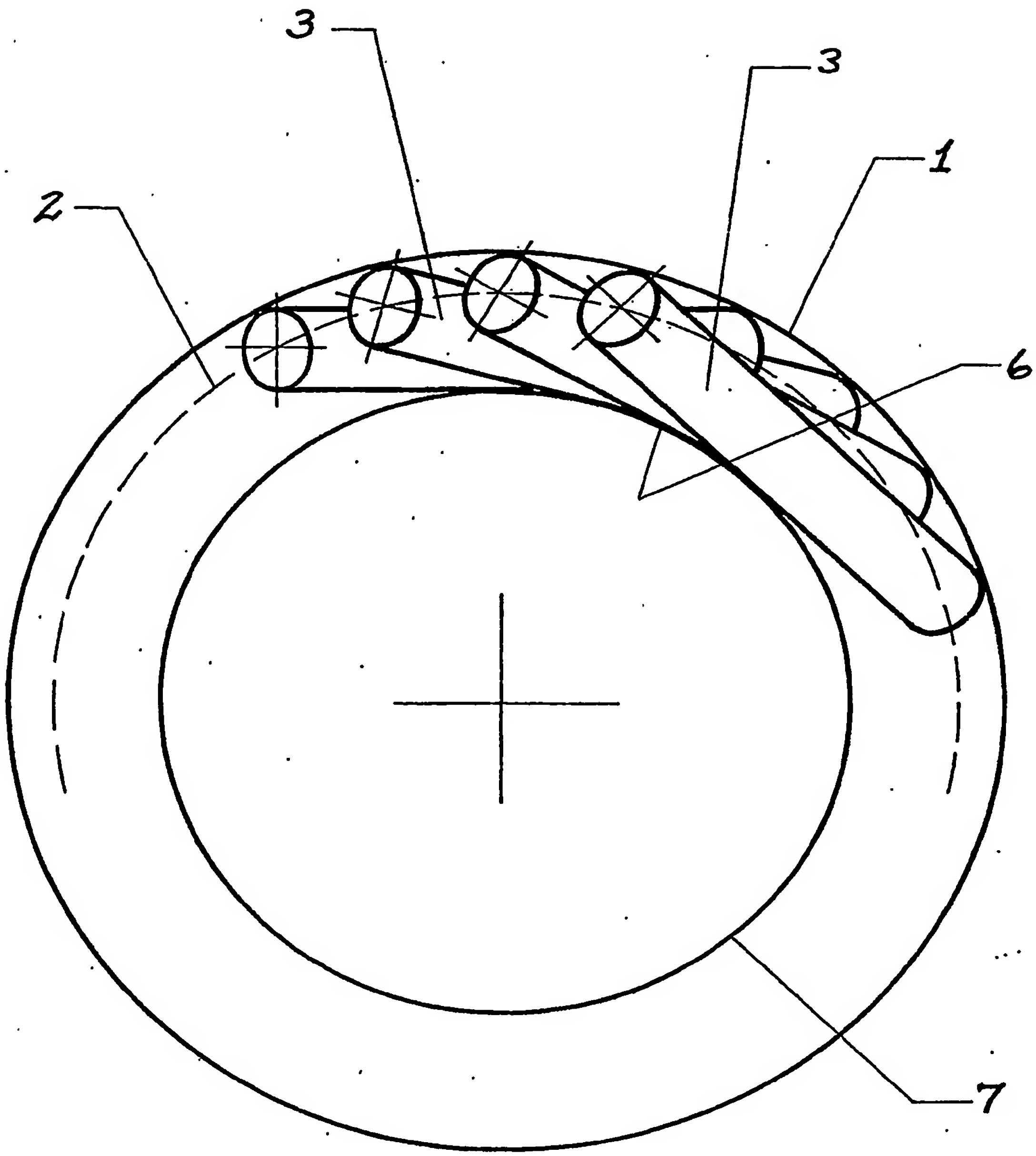


Fig 2

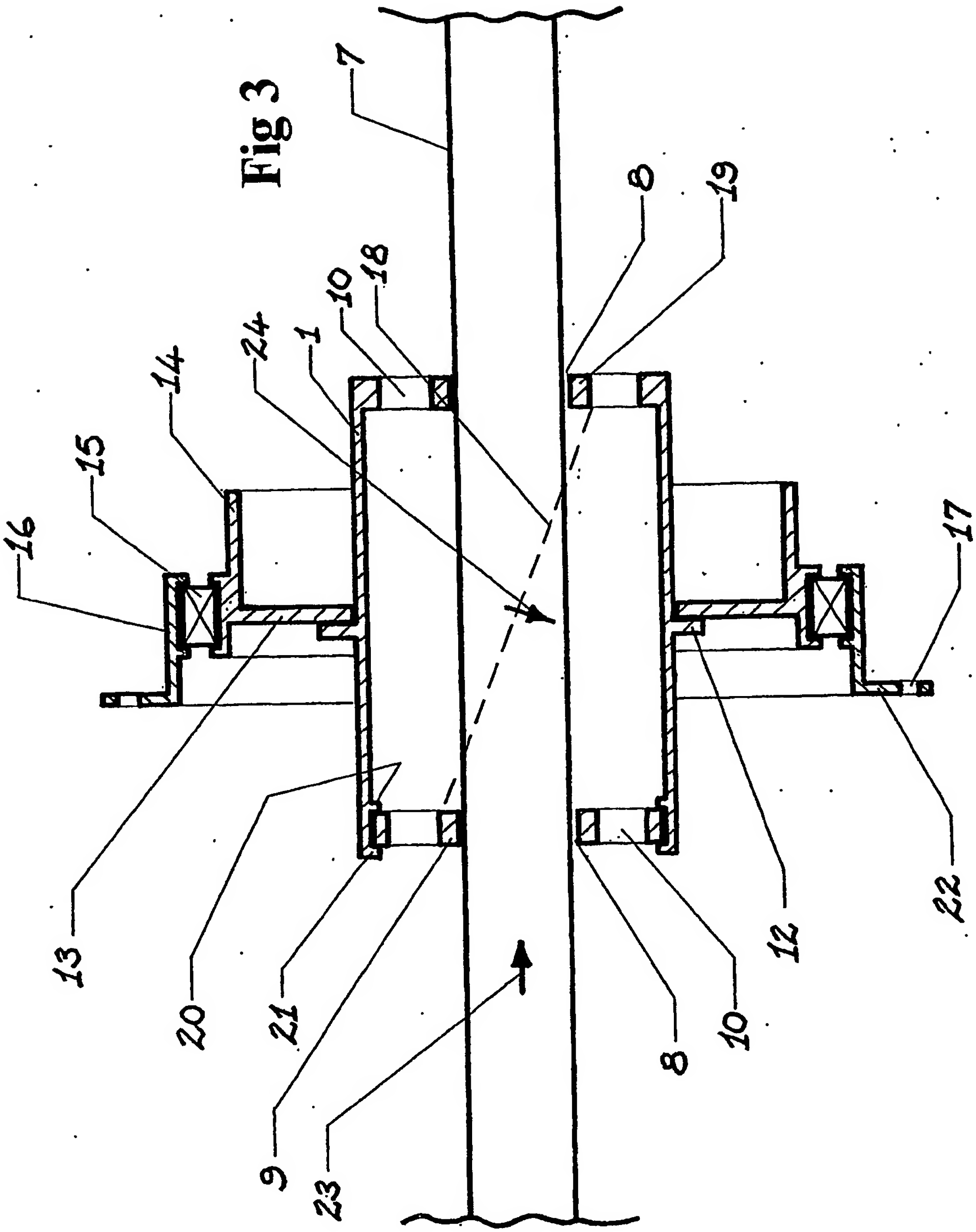
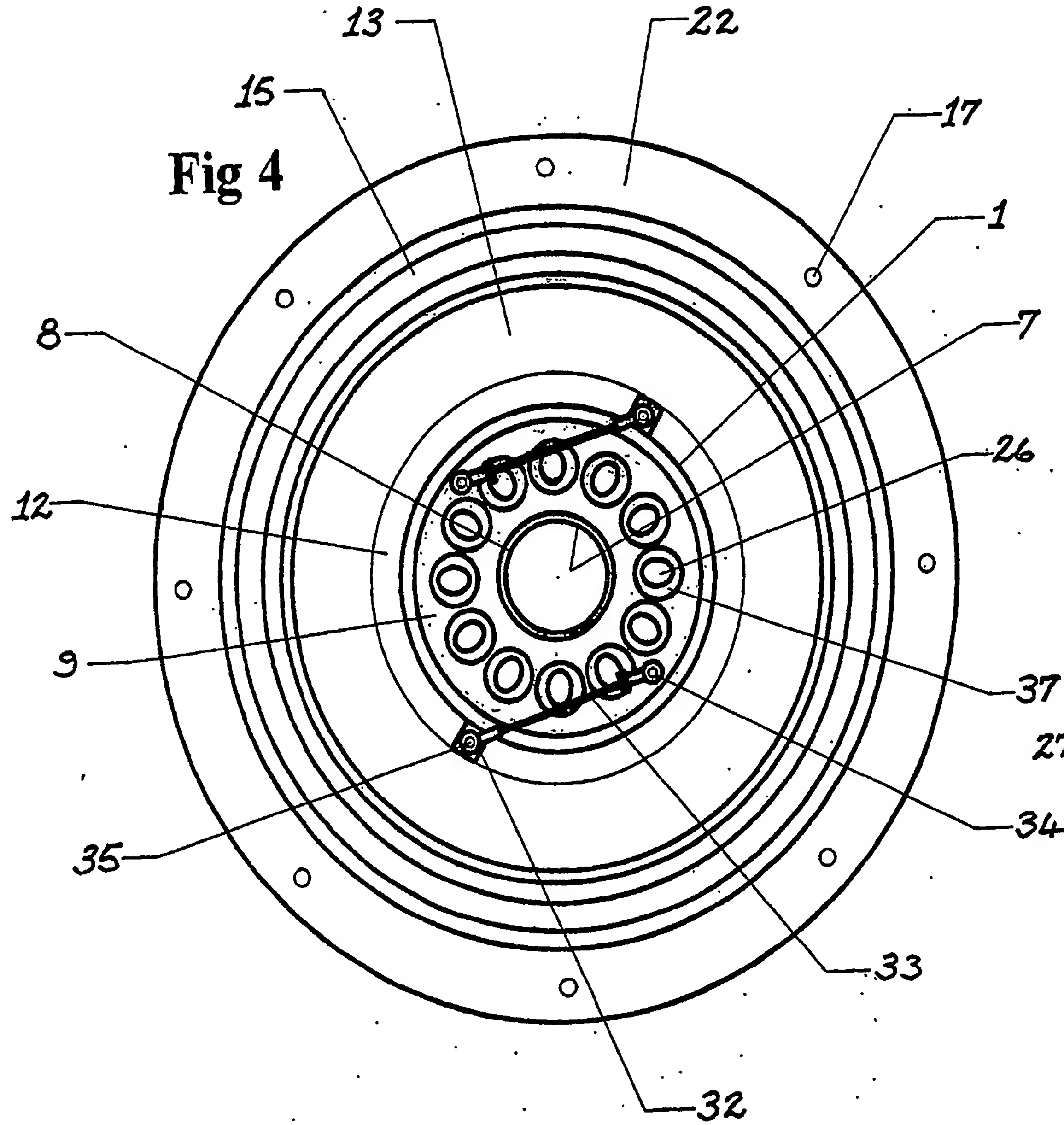


Fig 3

Fig 4



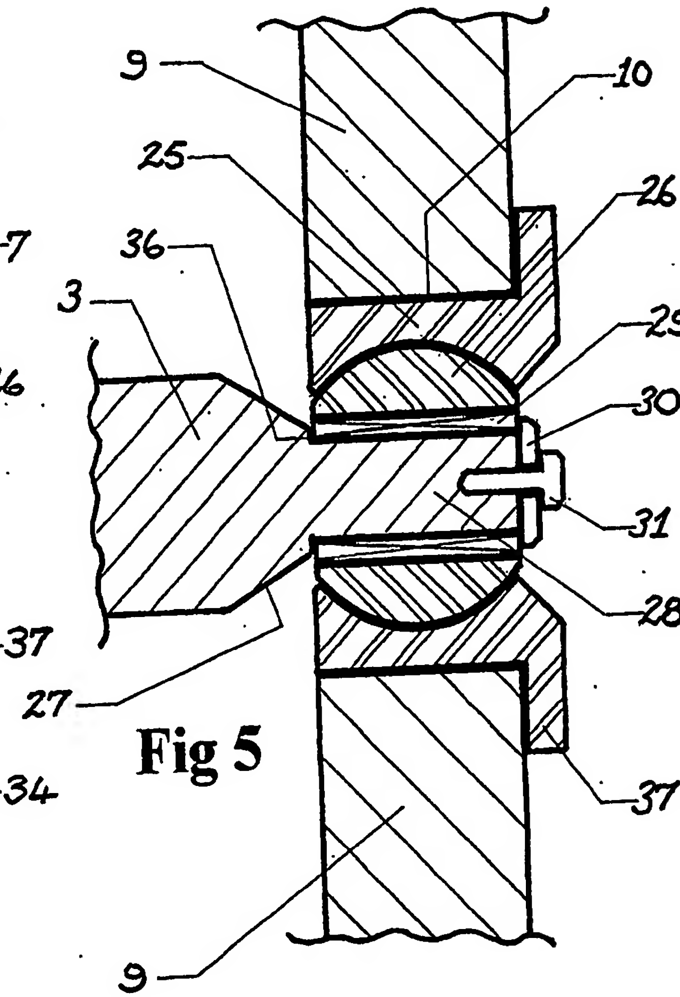


Fig 5

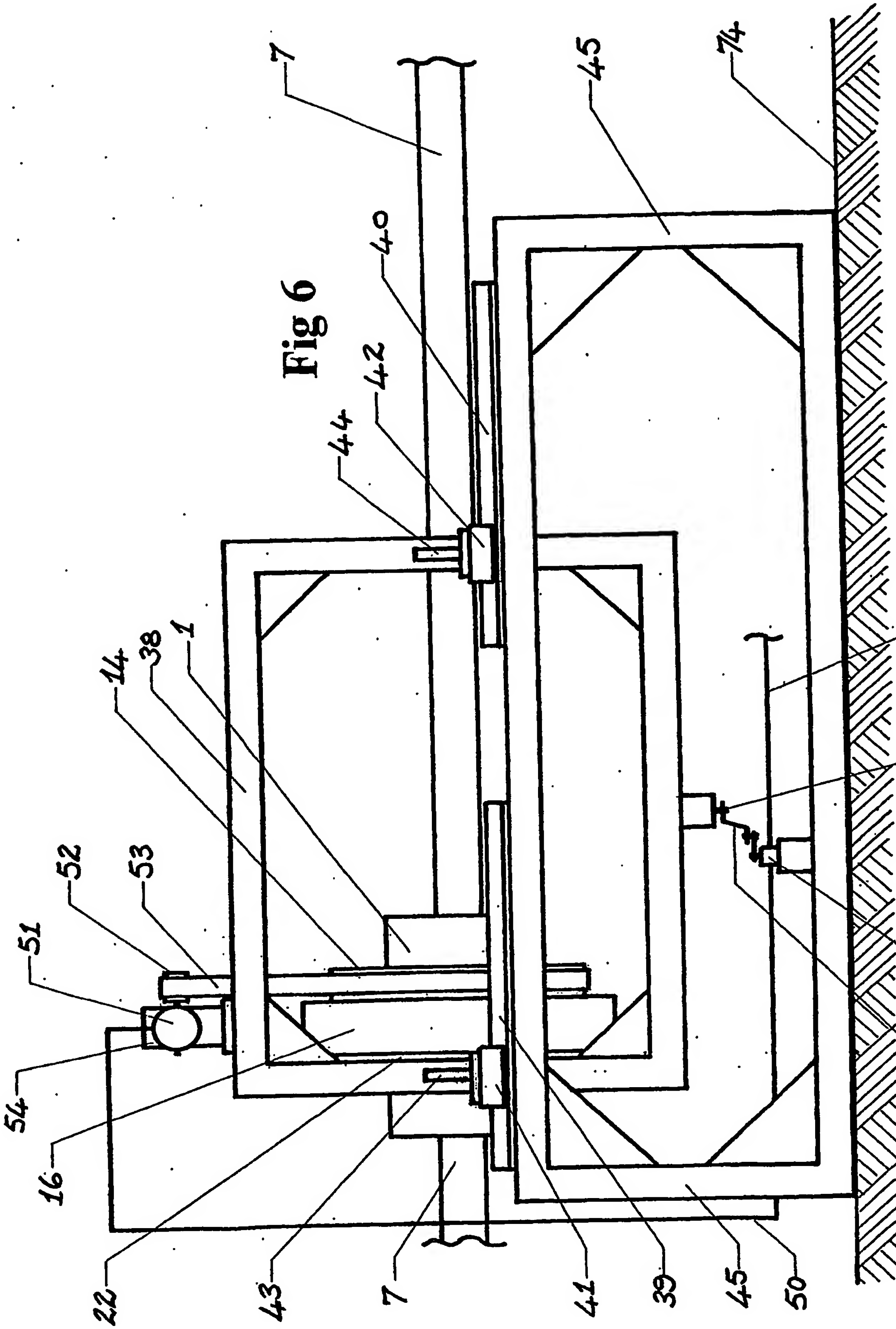


Fig 6

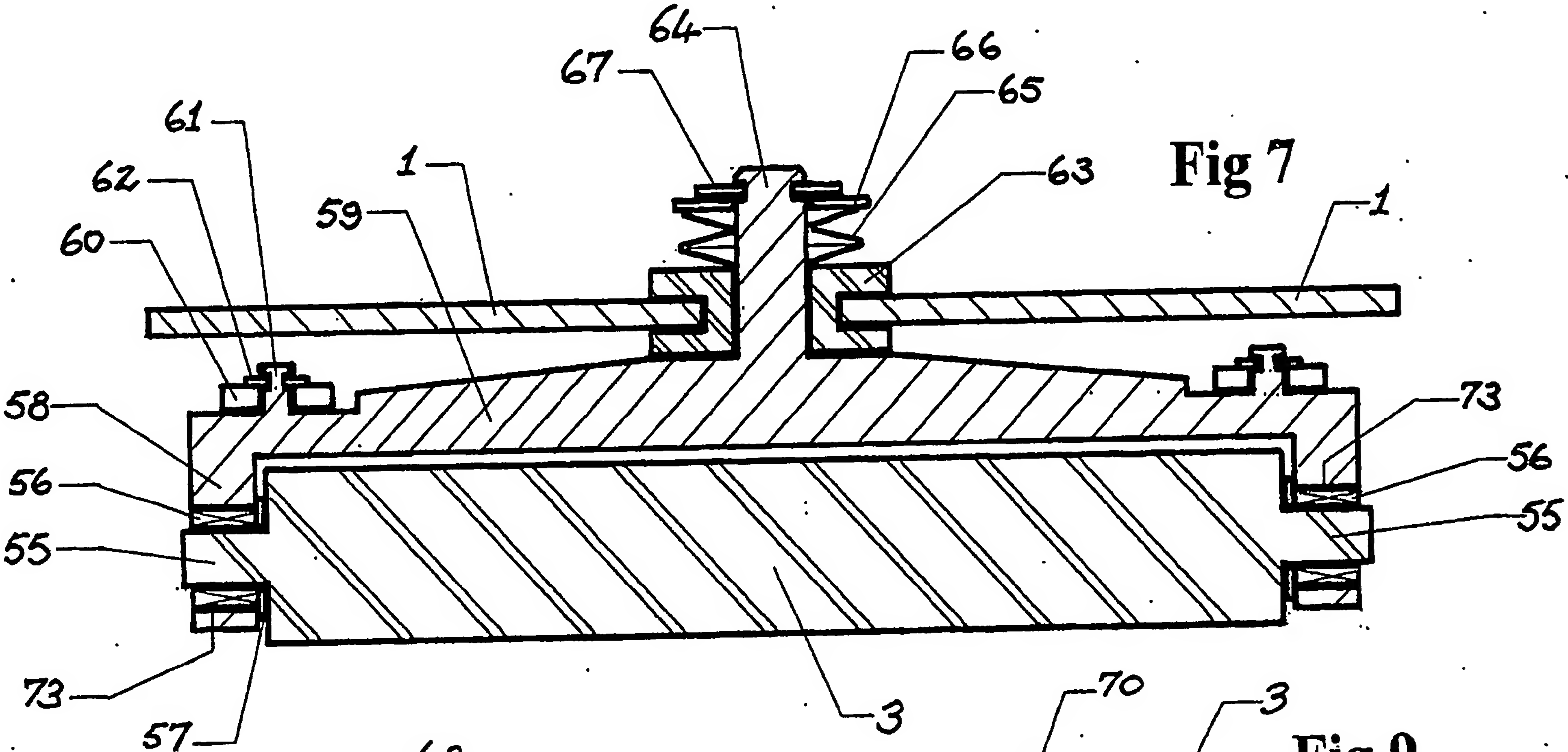
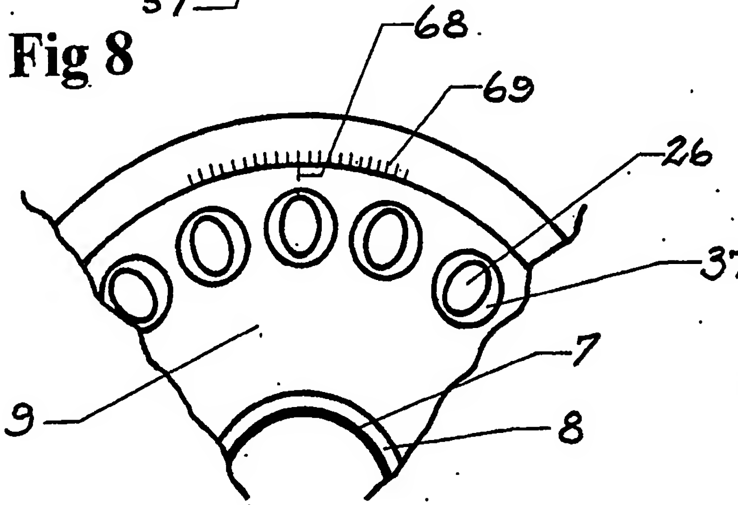


Fig 7

Fig 8



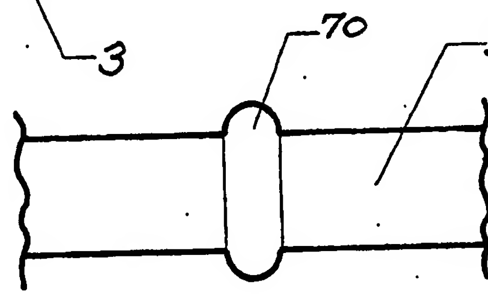


Fig 9

Fig 10